

## Potency of Culled Saanen Crossbred Goat in Supplying Raw Meat for Traditional Thai Butchery

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### ABSTRACT

Potency of culled Saanen crossbred goat meat to replace the supply of yearling Boer crossbred goat meat was evaluated. Selected muscles from leg and shoulder cuts were analysed for their nutritional (proximate composition, collagen, amino acids, fatty acids), physicochemical (pH, myoglobin, drip loss, cook loss, shear force, lightness (L\*) redness (a\*) yellowness (b\*), microstructure), and sensory (triangle test, hedonic test) evaluations. Meat samples from culled Saanen crossbred goat exhibited higher values in protein, collagen, and MUFA ( $P<0.05$ ) than those from Boer crossbred goat, while lower values in ash, soluble collagen, and SFA were obtained ( $P<0.05$ ). Meat from culled Saanen crossbred goat revealed higher cook loss, shear force, and redness compared to those from a yearling Boer crossbred goat ( $P<0.05$ ). In addition, thicker perimysium in meat of Saanen crossbred goat was obtained particularly that could be seen on leg part. In sensory evaluation result, the panels could detect the differences between raw meat characteristics of these goat breeds ( $P<0.05$ ) within the same muscle. However, the panels could not distinguish the difference between breeds in leg meat after being cooked. Shoulder meat of Saanen crossbred goat had less acceptance level compared to the other samples ( $P<0.05$ ) particularly on its texture and taste quality. In summary, shoulder cut of culled Saanen crossbred goat exhibited a well-intentioned potency to substitute the supply of meat from yearling Boer crossbred goat. Nevertheless, pre-treatment might be applied to leg cut of Saanen crossbred goat to solve the less acceptance level of its textural and taste characteristics.

**Keywords:** Saanen goat, Boer goat, goat meat quality, goat meat composition, microstructure of goat meat

### ABSTRAK

Potensi daging kambing peranakan Saanen tua untuk mensubstitusi suplai daging kambing peranakan Boer telah dievaluasi. Otot dari bagian kaki dan bahu telah dianalisis untuk melihat kandungan nutrisi (komposisi proksimat, kolagen, asam amino, dan asam lemak), sifat fisikokimia (pH, mioglobin, susut drip, susut masak, *shear force*, *lightness* (L\*) *redness* (a\*) *yellowness* (b\*), dan mikrostruktur), dan penilaian sensori (uji segitiga dan uji hedonik). Berdasarkan penelitian didapatkan bahwa kandungan protein, kolagen, dan MUFA daging kambing peranakan Saanen lebih tinggi ( $P<0.05$ ) daripada daging kambing peranakan Boer, sedangkan kadar abu, kolagen terlarut, dan SFA-nya lebih rendah ( $P<0.05$ ). Susut masak, *shear force*, dan *redness* daging kambing peranakan Saanen lebih tinggi daripada daging kambing peranakan Boer ( $P<0.05$ ). Selain itu, gambaran perimysium yang lebih tebal ( $P<0.05$ ) pada daging kambing peranakan Saanen telah didapatkan, terutama dapat dilihat pada bagian kaki. Pada penilaian sensori, panelis dapat membedakan daging mentah dari kedua bangsa kambing pada dua bagian karkas, tetapi panelis tidak dapat membedakan daging kaki di antara kedua bangsa kambing setelah dimasak. Daya terima panelis terhadap daging bahu paling rendah ( $P<0.05$ ) dibandingkan sampel lainnya, terutama terkait dengan kualitas tekstur dan rasanya. Dapat disimpulkan bahwa daging bagian bahu kambing peranakan Saanen berpotensi sebagai alternatif pengganti daging kambing peranakan Boer. Sementara itu, daging bagian kaki kambing peranakan Saanen memerlukan perlakuan lanjutan untuk mengatasi daya terimanya yang rendah terkait sifat tekstur dan rasanya.

**Kata kunci:** kambing Saanen, kambing Boer, kualitas daging kambing, komposisi daging kambing, mikrostruktur daging kambing

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## INTRODUCTION

In Thailand, goat is an alternative livestock that is increasingly raised for meat and milk purposes. From statistics data, the number of goats increased about 23.2% from 380,277 heads in the year of 2010 to 468,377 heads in the year of 2014 (DLD, 2015). Goat rearing is popular in Thai-Muslim community (Anothaisinthawee *et al.*, 2010; Seilsuth *et al.*, 2016), particularly in Southern Thailand that shows an increasing rate of goat meat consumption (Jittapalapong *et al.*, 2012). In general, goat reared traditionally under an extensive- or semi-intensive system using native goat breed supported with the availability of local feed sources.

Due to the lower performances of Thai native goat compared to the crossbred and pure bred goat (Supakorn *et al.*, 2011; Anothaisinthawee *et al.*, 2012), the Department of Livestock Development of Thailand imported several exotic breeds such as Boer, Anglo-Nubian, Saanen to upgrade Thai goat breed. Thai crossbred goat obtained from native female Thai x male Anglo-Nubian has been popularized since the last 30 years (Wasiksiri *et al.*, 2013). Moreover, among various latest breeding programs now, Boer is one of the most accepted meat-type goat in Thailand, and is being a popular goat breed for goat meat butchery. This was due to the Boer and its crossbred goats performed better with a higher live weight gain and provided a better carcass yield than the other exotic crossbred or native goats (Anothaisinthawee *et al.*, 2010; Anothaisinthawee *et al.*, 2012).

From 2009 to present, the demand of goat meat was generally increased while the number of meat goat is not sufficient to slaughter for Thai goat meat consumption. Thus, to substitute the consumer needs, meat from dairy goat, particularly Saanen, is used to compensate the meat for the meat goat. Although Saanen is a popular dairy-type goat due to its higher milk yield (Mioč *et al.*, 2007; Mioč *et al.*, 2008), meat from Saanen both buck and culled doe are commonly supplied to the local butcher. However, meat from culled Saanen does might be less tender due to the older age, so the price is lower than meat from Boer meat goat. In fact, it should be highlighted that traditional consumers in the market pay an attention to the meat yield rather than the meat quality. Thus, it is needed to compare the quality of culled Saanen milking goat with Boer goat meat.

The objective of this study was to compare nutritional, physicochemical, and sensory attributes of meat between Saanen crossbred and Boer crossbred goats. Information obtained from this study would be benefit for consumers, butchers, producers, and researchers to see the possibility of culled Saanen does as an alternative for goat meat demand. In addition, it could also be a consideration to decide an appropriate pre-treatment for culled Saanen goat for meat products if it is needed. Moreover, some variations among various muscles within similar goat breed could be obtained. Thus, it was important to determine meat characteristics between selected muscles in leg and shoulder.

## MATERIALS AND METHODS

### Materials

Four 5-year-old Saanen crossbred (87.5% Saanen x 12.5% Thai native; a main dairy breed reared in Thailand) and four 1-year-old Boer crossbred (75% Boer x 12.5% Anglo-Nubian x 12.5% Thai native; a main meat breed reared in Thailand) goats were obtained from Sitichai Dairy Goat Farm located in Sadao district, Songkhla, Thailand. Culled Saanen crossbred goats were raised under intensive system and were fed with chopped Napier grass (*Pennisetum purpureum*) *ad libitum* and concentrate was supplemented at 2.5% of body weight (14% crude protein (CP) and 3.2 Mcal/kg) to build up their body condition for about 3 months before being slaughtered. Boer crossbred goats were raised under a semi-intensive system when goats were kept in house and fed with chopped Napier grass *ad libitum* and concentrate diet (14% CP and 3.2 Mcal/kg) at 1.5% of body weight of each. Under a semi-intensive system, the experimental goats were allowed to graze on Ruzi grass (*Brachiaria ruziziensis*) paddock for about 3 to 4 h daily before being slaughtered.

The animals were transferred and slaughtered at Meat Laboratory, Department of Animal Science, Faculty of Natural Resources, Prince of Songkla University, Hat Yai District, Songkhla Province. The slaughtering procedure followed the guidelines enlightened in Thai Agricultural Standard 8400-2007 (National Bureau of Agricultural Commodity and Food Standards of Thailand, 2007) and Thai Agricultural Standard 9040-2013 (National Bureau of Agricultural Commodity and Food Standards of Thailand, 2013). After dressing the carcass using the skinning method, the carcass obtained was stored at 4°C/18 h for aging. Then, meats from the leg cut (*biceps femoris* and *semitendinosus*) and the shoulder cut (*supraspinatus* and *infraspinatus*) were selected for analyses. *Biceps femoris* and *supraspinatus* representing samples used for physicochemical analyses and sensory evaluation, while *semitendinosus* and *infraspinatus* representing samples used for fatty acid profiles determination.

### Methods

**Proximate analysis.** Proximate analysis was conducted based on the guidelines of the AOAC (2000). Moisture content was examined using oven drying, protein was measured using Kjeldahl, fat was investigated using soxhlet, and ash was obtained using dry ashing.

**Total collagen.** An acid hydrolysis method was applied to hydrolyse the protein from the sample as described by Palka (1999). HCl 6N was used to hydrolyse 0.5 g minced sample using an oil bath (110°C) for 24 h. After reaching ambient temperature, an activated charcoal-clarification, filtration, neutralization, and distilled water-dilution were conducted. After that, hydroxyproline was determined following the method explained by Bergman & Loxley (1963). The hydroxyproline content in sample was measured at the wavelength of 558nm

using a UV-spectrophotometer (UV-1700 PharmaSpec, Shimadzu Corporation, Japan). A 7.25 factor conversion was multiplied with hydroxyproline to convert the obtained diluted collagen into mg/g meat sample.

**Soluble collagen.** The extraction of meat soluble collagen was prepared following the procedure explained by Liu *et al.* (1996). A total of 2 g minced meat was mixed with 25% Ringer solution using a homogenizer (WiggenHauser®, Germany) for 1 min. A heating procedure of the homogenate in a water bath at 77°C for 70 min was applied. Then, the centrifugation of heated homogenate at 2300xg/30 min/4°C was conducted. Supernatant obtained from centrifugal separation was collected. The precipitate was extracted again as the same procedure explained. After that, the latter obtained supernatant was combined with the former one. The hydrolysis procedure followed the same method as explained in total collagen hydrolysis. The result of soluble collagen was reported as a percentage of total collagen.

**Fatty acid composition.** Lipid extraction was prepared for fatty acid determination by following the method described by Bligh & Dyer (1959). Then, the extracted lipids were esterified into fatty acid methyl esters (FAME) (Jham *et al.*, 1982). After that, fatty acid methyl esters were determined using Gas Chromatograph, 7890 (Agilent Technologies, USA) based on Gas Chromatography-Flame Ionization Detector technique.

**pH.** pH determination was measured using the guidelines explained by Wattanachant *et al.* (2004). A total of 1 g sample was mixed with 25 mL deionized water using a homogenizer (WiggenHauser®, Germany) for 1 min. A digital pH meter (SevenGo S62-FK2 Mettler Toledo, Switzerland) was used to measure the pH of the homogenate.

**Myoglobin.** An adapted method from Krzywicki (1982) was conducted to determine myoglobin content of the sample. The absorbance was determined at 572, 565, 545, and 525 nm using a UV-spectrophotometer (Libra S22 Biochrom, England). The total myoglobin content (Mmol/L) was calculated using the following formula:  

$$\text{Total myoglobin} = (-0.1666R_1 + 0.086R_2 + 0.088R_3 + 0.099) \times A_{525}$$
 where R<sub>1</sub>, R<sub>2</sub>, and R<sub>3</sub> are symbolised of A<sub>572</sub>/A<sub>525</sub>, A<sub>565</sub>/A<sub>525</sub>, and A<sub>545</sub>/A<sub>525</sub>, respectively.

A-16824 Da as molecular weight of goat myoglobin (Suman *et al.*, 2009; Suman & Joseph, 2013) was multiplied with the obtained myoglobin content to convert the result from Mmol/L of diluted myoglobin into mg/g of meat sample.

**Drip loss and cook loss.** Stainless steel surgical blade (Feather Safety Razor co Ltd., Japan) was used for sizing meat sample into 2x1x0.5 cm. For drip loss determination, the sample was blotted with multipurpose towel paper and weighed before being moved into a sealed plastic bag (size 4x6 cm). Then, the covered sample was stand on refrigerated temperature (4°C) for 24 h. After that, the sample was moved, blotted, and weighed again as was

conducted in the initial preparation. Finally, drip loss was determined based on post weight and initial weight of sample measured and reported in percentage. For cook loss determination, sealed-plastic bag samples were heated on a water bath (80°C) for 10 min. After that, heated sample was cooled, blotted and weighed as performed on the beginning preparation. Calculation of cook loss was similar to that of drip loss (Wattanachant, 2005).

**Texture.** Sizing procedure of sample was conducted with the same protocol used for determinations of drip loss and cook loss. Texture of sample was determined using a texture analyser (TA-XTplus Stable Micro System Texture Analyser, UK). A-2 mm/s cross head speed and a-50 kg load cell was fixed on such instrument. Score obtained after a Warner-Bratzler blade cut the sample representing shear force of sample (Dawson *et al.*, 1991).

**Color.** A Hunterlab colorimeter (Hunterlab ColorFlex, Virginia) was used to determine the color of sample. A black glass and a white standard tile were used to standardize the instrument before being applied for color measurement, respectively. Color was reported into lightness (L\*), redness (a\*), and yellowness (b\*) as used in International Commission on Illumination (CIE) system.

**Microstructure.** Microstructure determination was conducted using the method explained by Palka & Daun (1999) with slight modification. A sizing procedure of meat into 1x0.5x0.5 cm was applied carefully using similar razor blade used in sample preparation for drip loss, cook loss, and texture analyses. The specimen was, then, fixed in 0.1 M phosphate buffer pH 6.5 containing 2.5% glutaraldehyde. After 2 h room temperature fixation, a rinsing procedure using distilled water was applied. Every 1 h, then, a gradual dehydrated procedure using 25%, 50%, 70%, 95%, and absolute ethanol of specimen were conducted. The latter procedure were applied twice. A nitrogen-short dipping procedure was conducted on specimen before a thin-cutting process using razor blade was performed. After the remaining of non solid substance was removed using critical point dryer (Polaron CPD7501, East Sussex, UK), the thin fragments were placed on an aluminium stubs and then a gold coating procedure was applied using sputter coater (West Chester, PA, USA). Then, the photograph of sample was taken using a SEM on 10 kV accelerating voltage. A 500x (cross section) and a 10.000x (longitudinal section) magnification were used. Afterward, muscle fibre diameter and sarcomere length were determined using planimeter and vernier caliper, respectively. Fifteen measurements in each three video prints obtained were examined both for muscle fibre diameter and sarcomere length.

**Sensory evaluation.** Sensory evaluation was divided into triangle test and hedonic test following the general guidelines explained by Meilgaard *et al.* (2016). Thirty panels used both for triangle and hedonic test. Three digit numbers were used to code the samples served. In triangle test, the panels were served with one set of raw sample containing three meat pieces (two identical



samples and one odd sample). The panel was asked to determine the odd sample. The determination of samples in triangle test was conducted for both raw leg and shoulder meat. In hedonic test, samples were prepared by cooking until reaching 80°C of end point temperature using boiling method. Then, the plain cooked samples were served to the panels. Nine-point-hedonic scale (1= dislike extremely, 9= like extremely) was applied to determine the preferences level for color, texture, taste, aroma, and overall acceptances.

**Statistical analysis.** This study was conducted using completely randomized design (CRD) for physicochemical analyses. The model of this design was  $Y_{ij} = \alpha + \tau_j + \varepsilon_{ij}$ , where  $Y_{ij}$  was an observed value,  $\alpha$  was an overall mean,  $\tau$  was a fixed effect of treatment  $i$ , and  $\varepsilon_{ij}$  was a random effect. In particular for sensory preference, randomized complete block design (RCBD) was applied through the following model:  $Y_{ij} = \alpha + \beta_i + \tau_j + \varepsilon_{ij}$ , where  $Y_{ij}$  was an observed value,  $\alpha$  was an overall mean,  $\beta$  was a block effect or panel effect  $i$ ,  $\tau$  was a fixed effect of treatment  $j$ , and  $\varepsilon_{ij}$  was a random effect. Statistical data analyses of physicochemical and sensory preferences were subjected to a one way ANOVA followed by Duncan's New Multiple Range Test using SPSS Statistics at 0.05 significant level. Significance in triangle test (0.05) was determined based on critical number (minimum) of correct answers as described by Meilgaard *et al.* (2016).

## RESULTS

The result of nutritional composition and physicochemical characteristics of meat from yearling Boer and culled Saanen goats is presented in Table 1. Protein content of Saanen goat meat was considerably higher than that of Boer goat meat, while its intramuscular fat content exhibited a lower trend. Lower trend of fat content in Saanen meat compared to that of Boer meat was performed. Total collagen of meat from Saanen goat was higher than that of Boer goat within the same cut, while lower soluble collagen percentage of leg of Saanen goat meat was obtained. Saanen goat meat contained substantial lower saturated fatty acid (SFA) compared to Boer goat meat, while its monounsaturated fatty acids (MUFA) were higher. At the same time, polyunsaturated fatty acids (PUFA) of meat between breeds were not different.

pH of meat was varied between cuts, while meats from the leg cuts exhibited higher pH than those of the shoulders. Cook loss and shear force of Saanen goat meat were significantly higher than those of Boer goat meat, while its lightness was significantly lower. At the same time, the myoglobin content of the samples was not much different. The non-significant differences were obtained in the microstructure of samples both fibre diameter and sarcomere length. However, higher standard deviations in Saanen goat meat than those of Boer goat meat were obtained. Scanning electron micrographs of cross and longitudinal sections of muscles from culled Saanen crossbred and Boer crossbred goats are presented in Figure 1. From this Figure, it could be seen that fibre diameter among samples were not much

different. Muscles structure of Saanen crossbred goat had thicker perimysium and endomysium compared to those of Boer crossbred goat, especially in leg perimysium. Moreover, smaller muscle fibre near the perimysium of meat from both breeds was obtained. At the same time, comparable sarcomere length in all samples were observed.

The results of sensory characteristics among goat meat samples were provided in Table 2. In triangle test, significant difference between breeds was found in raw leg, raw shoulder, and cooked leg samples, while no significance difference was obtained in cooked shoulder samples. In hedonic test, significant differences between breeds and muscle cuts were obtained for texture, taste, flavor, and overall acceptability. Moreover, texture and taste of leg meat from Saanen crossbred goat had the least acceptance level.

## DISCUSSION

Higher protein contents obtained from Saanen samples related to the higher formation of collagen with the increasing age of the goat. The trend is similar with the result between dairy cattle (22.39%) vs beef cattle (20.85%) (Lizaso *et al.*, 2011). It was noticed that dairy breed reached earlier maturity than beef breed (Wondifraw *et al.*, 2013). Maturity level of animal breed determines collagen properties. Earlier mature animals were characterized by the higher collagen deposition (Jurie *et al.*, 2007). Fat deposition between breeds is more associated with different locations of fat deposite. Visually, fat deposition of Saanen carcass could be seen in the form of adipose tissue in some areas between muscles as energy reserver rather than in intramuscular fat in the muscle. The phenomenon of the importance of adipose tissue as energy reserver in dairy breed was explained in Mishra *et al.* (2016).

Grain-concentrate feed provided for Saanen goat (2.5%/d) was higher than that of Boer goat (1.5%/day). In line with previous study, cattle finished on concentrate (45.91%) presented a higher MUFA deposition compared to forage-finished (35.93%) (Duckett *et al.*, 2013). Grain-concentrate either commercial or self-manufactured by farmers was unsaturated-rich components. Deposition of unsaturated-rich components in muscle was responsible for this phenomenon.

The phenomenon occurred in pH might be related to the glycogen concentration. Glucose as a source of energy stored as glycogen is mostly in skeletal muscle (Ostrowska *et al.*, 2015). Selected muscle in leg cut (*biceps femoris*) plays more activity movement during daily life, while selected muscle in shoulder cut (*supraspinatus*) attached near the bond and thus less active during animal movement. More active muscle used more glycogen concentration during daily activity. Thus, this condition lead to a less remaining of glycogen in leg cut could be converted to lactate to decrease the pH.

The older the age as in culled Saanen, the longer the activity of animal and thus produce more myoglobin to bind oxygen to support the activity. At the same time, even though Boer were in yearling age, they have more activity due to their visits to paddock. Thus,

Table 1. Nutritional composition and physicochemical characteristics of meat from culled Saanen crossbred and yearling Boer crossbred goats

Parameter	Saanen leg	Saanen shoulder	Boer leg	Boer shoulder
Proximate				
Moisture (%)	77.01±0.99	76.79±0.50	76.90±0.89	76.69±0.54
Protein (%)	20.19±0.89 <sup>a</sup>	19.40±0.97 <sup>ab</sup>	18.82±0.98 <sup>ab</sup>	18.54±0.53 <sup>c</sup>
Fat (%)	2.32±0.69 <sup>b</sup>	2.70±0.21 <sup>ab</sup>	2.63±0.44 <sup>ab</sup>	3.22±0.43 <sup>a</sup>
Ash (%)	1.05±0.01 <sup>b</sup>	1.08±0.02 <sup>ab</sup>	1.09±0.03 <sup>a</sup>	1.10±0.02 <sup>a</sup>
Collagen				
Total collagen (mg/g)	5.96±1.72 <sup>a</sup>	5.00±0.67 <sup>ab</sup>	3.06±0.74 <sup>c</sup>	3.90±0.45 <sup>bc</sup>
Soluble collagen (%)	7.34±2.59 <sup>b</sup>	11.36±4.92 <sup>ab</sup>	13.51±2.53 <sup>a</sup>	12.57±3.15 <sup>ab</sup>
Fatty acid (% ratio)				
C9:0	ND	ND	ND	ND
C10:0	0.06±0.02	0.05±0.03	0.24±0.27	0.15±0.08
C11:0	ND	ND	ND	ND
C12:0	0.20±0.08 <sup>ab</sup>	0.23±0.08 <sup>a</sup>	0.10±0.01 <sup>c</sup>	0.13±0.00 <sup>bc</sup>
C13:0	0.01±0.00	0.04±0.08	0.01±0.01	0.01±0.01
C14:0	2.59±0.45	2.73±0.44	2.10±0.31	2.43±0.32
C15:0	0.43±0.07	0.43±0.08	0.51±0.10	0.57±0.12
C16:0	24.94±1.86 <sup>ab</sup>	26.26±1.12 <sup>a</sup>	22.77±0.68 <sup>bc</sup>	24.23±1.05 <sup>c</sup>
C16:1	3.63±0.33 <sup>a</sup>	3.30±0.72 <sup>a</sup>	2.11±0.31 <sup>b</sup>	1.70±0.91 <sup>b</sup>
C17:0	1.06±0.20 <sup>b</sup>	1.04±0.12 <sup>b</sup>	1.51±0.24 <sup>a</sup>	1.48±0.29 <sup>a</sup>
C18:0	14.29±2.53 <sup>b</sup>	14.44±1.99 <sup>b</sup>	24.12±3.36 <sup>a</sup>	23.83±3.34 <sup>a</sup>
C18:1	46.84±1.78 <sup>a</sup>	45.24±3.22 <sup>ab</sup>	39.65±3.97 <sup>b</sup>	40.80±4.69 <sup>b</sup>
C18:2	4.83±1.41	5.34±2.68	4.52±0.48	2.84±2.00
C18:3	0.16±0.11 <sup>b</sup>	0.23±0.02 <sup>b</sup>	1.47±0.26 <sup>a</sup>	1.22±0.17 <sup>a</sup>
C20:0	0.09±0.02	0.04±0.06	0.04±0.08	0.07±0.27
C20:1	0.26±0.07 <sup>a</sup>	0.26±0.06 <sup>a</sup>	0.04±0.04 <sup>b</sup>	0.04±0.04 <sup>b</sup>
C22:0	ND	ND	ND	ND
C22:1	ND	ND	ND	ND
C24:0	0.40±0.27	0.30±0.37	0.46±0.47	0.32±0.28
C24:1	ND	ND	ND	ND
SFA	44.11±1.77 <sup>b</sup>	45.60±2.51 <sup>b</sup>	52.01±4.74 <sup>a</sup>	53.27±5.06 <sup>a</sup>
MUFA	50.91±1.98 <sup>a</sup>	48.83±3.88 <sup>ab</sup>	42.01±4.56 <sup>b</sup>	42.68±5.81 <sup>b</sup>
PUFA	4.99±1.47 <sup>a</sup>	5.57±2.69 <sup>a</sup>	5.98±0.32 <sup>a</sup>	4.05±2.04 <sup>a</sup>
UFA	55.89±1.76 <sup>a</sup>	54.40±2.53 <sup>a</sup>	47.99±4.74 <sup>b</sup>	46.74±5.07 <sup>b</sup>
SFA/UFA	0.79±0.05 <sup>b</sup>	0.84±0.08 <sup>b</sup>	1.10±0.20 <sup>a</sup>	1.16±0.23 <sup>a</sup>
Physicochemical				
pH	6.04±0.15 <sup>a</sup>	5.76±0.08 <sup>b</sup>	6.23±0.32 <sup>a</sup>	5.86±0.14 <sup>b</sup>
Myoglobin (mg/g)	11.30±1.83 <sup>a</sup>	10.63±1.78 <sup>a</sup>	9.90±1.11 <sup>a</sup>	9.93±1.16 <sup>a</sup>
Drip loss (%)	1.60±0.20 <sup>b</sup>	2.21±0.60 <sup>a</sup>	1.60±0.35 <sup>b</sup>	1.53±0.15 <sup>b</sup>
Cook loss (%)	38.75±1.03 <sup>a</sup>	38.78±0.60 <sup>a</sup>	35.87±1.62 <sup>b</sup>	35.98±0.33 <sup>b</sup>
Shear force	4.64±0.45 <sup>a</sup>	4.34±0.37 <sup>ab</sup>	3.83±0.46 <sup>bc</sup>	3.50±0.38 <sup>c</sup>
Lightness (L*)	33.12±0.96 <sup>b</sup>	34.44±0.90 <sup>b</sup>	39.85±1.16 <sup>a</sup>	40.88±1.73 <sup>a</sup>
Redness (a*)	16.71±1.10 <sup>a</sup>	15.83±0.99 <sup>ab</sup>	15.08±0.82 <sup>ab</sup>	14.36±0.66 <sup>b</sup>
Yellowness (b*)	12.18±1.22	11.93±0.51	10.36±2.75	10.82±2.33
Fibre diameter (µm)	32.51±3.07	33.30±4.47	30.23±1.50	31.67±2.96
Sarcomere length (µm)	1.42±0.19	1.46±0.11	1.31±0.14	1.30±0.06

Note: Means in the same rows with different superscripts differ significantly ( $P < 0.05$ ). ND= not detected.

older age and limited movement of Saanen goat makes a balance condition toward younger age and higher movement of Boer goats. This phenomenon is similar with the age- (Kim *et al.*, 2012) and activity-related fac-

tors (Huuskonen *et al.*, 2010) implied from the results of previous studies.

During heating, structure of collagen would be initially denatured and shrinkaged particularly on its peri-

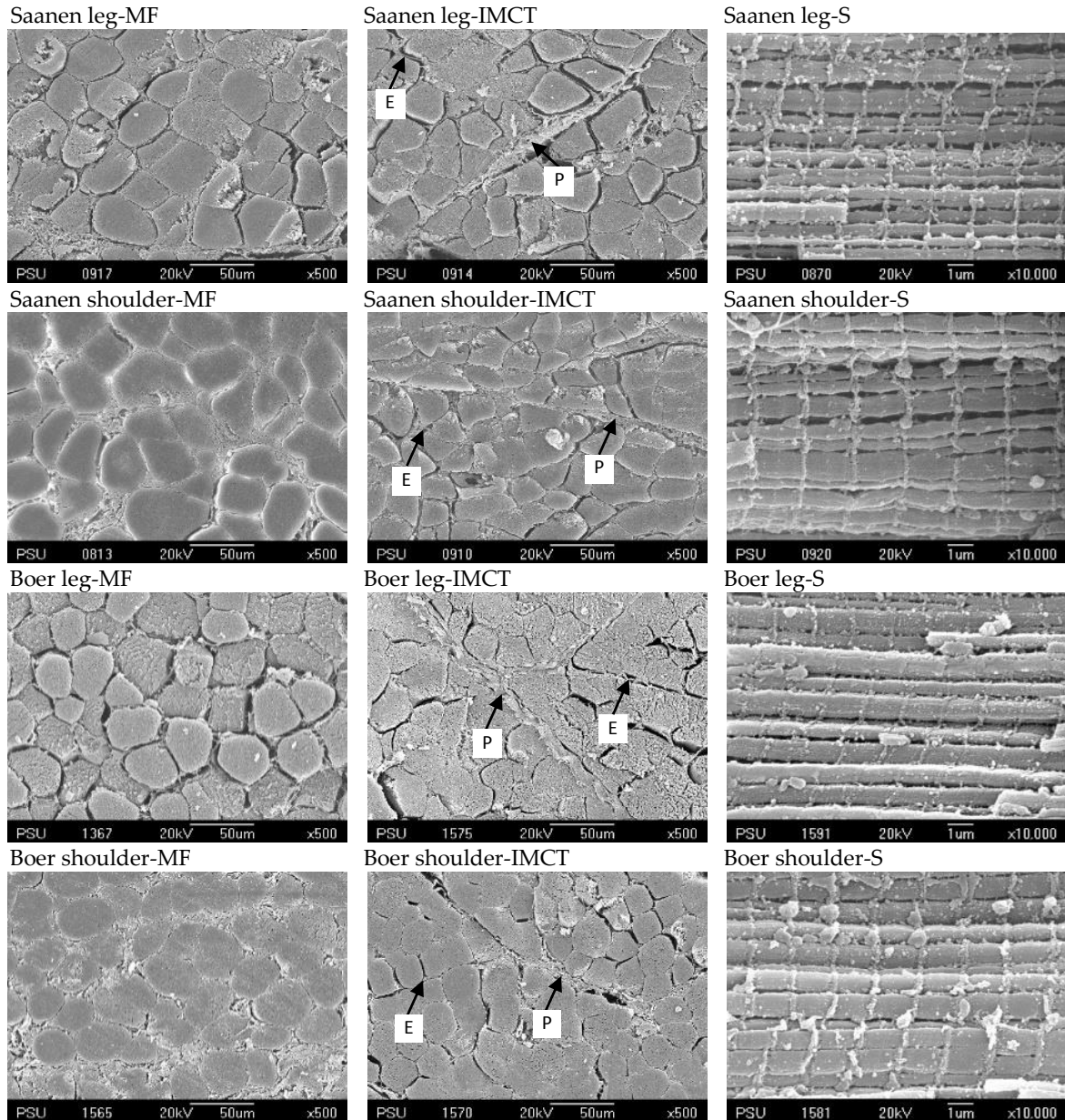


Figure 1. Scanning electron micrographs of cross and longitudinal sections of leg and shoulder from culled Saanen crossbred and yearling Boer crossbred goats. Note: MF= muscle fibre, IMCT= intramuscular connective tissue, S= sarcomere, P= perimysium, E= endomysium. \_\_\_\_ with x500 magnification in muscle fibre (MF) and intramuscular connective tissue (IMCT) micrographs was equivalent to 50 µm, \_\_\_\_ with x100.000 magnification in sarcomere (S) micrograph was equivalent to 1 µm.

Table 2. Sensory evaluation of meat from culled Saanen crossbred and yearling Boer crossbred goats

Sensory evaluation				
Triangle test	Raw leg	Raw shoulder	Cooked leg	Cooked shoulder
Significance	P<0.05	P<0.05	P<0.05	P≥0.05
Hedonic test	Boer leg	Boer shoulder	Saanen leg	Saanen shoulder
Color	5.97±1.97	6.57±1.74	6.13±1.80	6.23±1.48
Texture	5.83±1.84 <sup>b</sup>	6.93±1.72 <sup>a</sup>	4.57±2.03 <sup>c</sup>	6.13±1.66 <sup>ab</sup>
Taste	5.67±1.81 <sup>b</sup>	6.53±1.28 <sup>a</sup>	5.00±1.97 <sup>c</sup>	5.77±1.81 <sup>b</sup>
Flavor	5.77±1.85 <sup>ab</sup>	6.13±1.80 <sup>a</sup>	5.00±2.23 <sup>c</sup>	5.77±1.68 <sup>ab</sup>
Overall acceptance	5.83±1.64 <sup>bc</sup>	6.73±1.28 <sup>a</sup>	5.27±1.82 <sup>c</sup>	6.07±1.48 <sup>b</sup>

Note: Means in the same rows with different superscripts differ significantly (P<0.05)



mysium and endomysium. Then, collagen solubilisation gradually occurred (Chang *et al.*, 2011). As a result, some water progressively comes out from muscle fibre. Thus, a higher cook loss performed in Saanen goat might be related to its higher collagen content. It was also reliable that, to some degree, higher collagen percentage might be lowering myofibrillar protein percentage. Then, sample with less myofibrillar content was also going into limited ability to hold water.

A higher shear force found in Saanen goat meat was directly related to its collagen content. Besides, Saanen goat meat also had less soluble collagen percentage than that of Boer goat meat particularly on leg part. This represented that Saanen leg had a higher cross linking collagen, which lead to tougher texture. In addition, thicker perimysium in Boer leg (Figure 1) supports this phenomenon. A research reported by Ding *et al.* (2010) also found a higher shear force in the meat from dairy goat compared to that of its crossing with Boer goats.

A slightly higher trend in fat of Saanen samples might lead to a significant effect on lightness (L\*) as was also noticed in positive correlation of fatness-lightness reported by Węglarz (2010). Other possible factor such as variation of oxidative stability of myoglobin (Adeyemi *et al.*, 2016) might be also reliable to elucidate the higher difference in meat lightness.

Some muscle fibres in Saanen crossbred goat might be developed well and bigger as the effect of age, while some others had limited development resulted from less mobility and thus leading to a high variation of fibre diameter. At the same time, muscle fibre in the Boer crossbred goat developed in a better way by less variation size due to a routine activity in a wider area (paddock). As explained by Joo *et al.* (2013), total number and cross section area of fibre were related with its contractile function and fibre type composition. In addition, muscle structure of Saanen goat meat had thicker perimysium and endomysium, especially in leg perimysium.

Result in triangle test reflected that panels could detect difference of meat between breeds in both raw leg and shoulder samples. In brief, texture of sample resulted more effect in triangle test. At the same time, difference in cooked leg samples between Boer crossbred and Saanen crossbred meat also detectable. Lower soluble collagen percentage in Saanen leg representing a higher collagen crosslinking as also found in bulls as explained by Christensen *et al.* (2011). The more collagen crosslinking caused less collagen solubilization. Thus, the structure still tougher than Boer shoulder after being cooked. Similar collagen percentage between shoulder cuts of both breeds resulted comparable cooked condition. Less perimysium in meat of shoulder cut caused more heat energy to rupture meat structure during heating.

In hedonic score, texture and taste of leg meat from Saanen goat had the least acceptance level. This was due to the tougher texture intensity obtained from such sample. Besides, the higher trend of MUFA on leg meat might attribute to a more oxidation during cooking. The difference in fatty acid composition might be the most substantial factors to explain the triangle test result in leg cooked samples.

## CONCLUSION

Meat from Saanen crossbred goat was healthier as related to its higher MUFA percentage. However, extra proper handling would be required since lipid oxidation was possibly prone to be oxidized in this sample. Tougher texture resulted in selected muscle in raw leg Saanen crossbred samples revealed the comparable occurrence after cooking as implied from the result in the triangle test. Shear force and fatty acids might contribute more impact to make a difference in sensory acceptance. Meat from selected muscles of shoulder cut of Saanen crossbred could be directly used to substitute Boer crossbred meat. However, the meat from selected muscles of leg cut of Saanen crossbred goat needed pretreatment before being cooked to solve its textural and taste challenging.

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## REFERENCES

- Adeyemi, K. D., R. M. Shittu, A. B. Sabow, M. Ebrahimi, & A. Q. Sazili. 2016. Influence of diet and post-mortem ageing on oxidative stability of lipids, myoglobin and myofibrillar proteins and quality attributes of gluteus medius muscle in goats. *PLoS ONE*. 11:1-15. <https://doi.org/10.1371/journal.pone.0154603>
- Anothaisinthawee, S., K. Nomura, T. Oishi, & T. Amano. 2010. Goat genetic resources and breeding strategies in Thailand. *J. Anim. Genet.* 38:41-48. <https://doi.org/10.5924/abgri.38.41>
- Anothaisinthawee, S., C. Wattanachant, K. Nomura, T. Oishi, & T. Amano. 2012. Carcass and meat quality of three genotype populations in goat breeding for meat purposes in Thailand. *J. Agr. Sci.* 57:63-70.
- AOAC. 2000. Official Methods of Analysis of AOAC International. 17th ed. Association of Official Analytical Chemists (AOAC) International, Maryland.
- Bergman, I., & R. Loxley. 1963. Two improved simplified methods for the spectrophotometric determination of hydroxyproline. *Anal. Chem.* 35:1961-1965. <https://doi.org/10.1021/ac60205a053>
- Bligh, E. G., & W. J. Dyer. 1959. A rapid method of total lipid extraction and purification. *Can. J. Biochem. Physiol.* 37:911-917. <https://doi.org/10.1139/o59-099>
- Chang, H., Q. Wang, X. Xu, C. Li, M. Huang, G. Zhou, & Y. Dai. 2011. Effect of heat-induced changes of connective tissue and collagen on meat texture properties of beef semitendinosus muscle. *Int. J. Food Prop.* 14:381-396. <https://doi.org/10.1080/10942910903207728>
- Christensen, M., P. Ertbjerg, S. Failla, C. Sa-udo, R. I. Richardson, G. R. Nute, J. L. Olleta, B. Panea, P. Alberti, M. Juárez, J.-F. Hocquette, & J. L. Williams. 2011. Relationship between collagen characteristics, lipid content and raw and cooked texture of meat from young bulls of fifteen European breeds. *Meat Sci.* 87:61-65. <https://doi.org/10.1016/j.meatsci.2010.09.003>
- Dawson, P. L., B. W. Sheldon, & J. J. Miles. 1991. Effect of aseptic processing on the texture of chicken meat. *Poult. Sci.*

- 70:2359-2367. <https://doi.org/10.3382/ps.0702359>
- Ding, W., L. Kou, B. Cao, & Y. Wei. 2010. Meat quality parameters of descendants by grading hybridization of Boer goat and Guanzhong dairy goat. *Meat Sci.* 84:323-328. <https://doi.org/10.1016/j.meatsci.2009.04.015>
- DLD. 2015. Statistic of Goat in Thailand Year 2014. Department of Livestock Development (DLD), Ministry of Agriculture, Thailand. <http://ict.dld.go.th/th2/index.php/th/report/196-report-thailand-livestock/reportservey2557/700-report-survey57-1> [1May 1, 2015].
- Duckett, S. K., J. P. S. Neel, R. M. Lewis, J. P. Fontenot, & W. M. Clapham. 2013. Effects of forage species or concentrate finishing on animal performance, carcass and meat quality. *J. Anim. Sci.* 91:1454-1467. <https://doi.org/10.2527/jas.2012-5914>
- Huuskonen, A., E. Joki-Tokola, M. Honkavaara, L. Tuomisto, & R. Kauppinen. 2010. Meat quality and fatty acid profile of *M. longissimus dorsi* of growing bulls under insulated, uninsulated and outdoor housing conditions. *Agric. Food Sci.* 19:214-222. <https://doi.org/10.2137/145960610792912620>
- Jham, G. N., F. F. Teles, & L. G. Campos. 1982. Use of aqueous HCl/MeOH as esterification reagent for analysis of fatty acids derived from soybean lipids. *J. Am. Oil Chem. Soc.* 59:132-133. <https://doi.org/10.1007/BF02662261>
- Jittapalapong, S., S. Saengow, N. Pinyopanuwat, W. Chimnoi, W. Khachaeram, & R. W. Stich. 2012. Gastrointestinal helminthic and protozoal infections of goats in Satun, Thailand. *J. Trop. Med. Parasitol.* 35:48-54.
- Joo, S. T., G. D. Kim, Y. H. Hwang, & Y. C. Ryu. 2013. Control of fresh meat quality through manipulation of muscle fiber characteristics. *Meat Sci.* 95:828-836. <https://doi.org/10.1016/j.meatsci.2013.04.044>
- Jurie, C., B. Picard, J. -F. Hocquette, E. Dransfield, D. Micol, & A. Listrat. 2007. Muscle and meat quality characteristics of Holstein and Salers cull cows. *Meat Sci.* 77:459-466. <https://doi.org/10.1016/j.meatsci.2007.04.014>
- Kim, Y. H. B., A. Stuart, C. Black, & K. Rosenvold. 2012. Effect of lamb age and retail packaging types on the quality of long-term chilled lamb loins. *Meat Sci.* 90:962-966. <https://doi.org/10.1016/j.meatsci.2011.11.040>
- Krzywicki, K. 1982. The determination of haem pigments in meat. *Meat Sci.* 7:29-36. [https://doi.org/10.1016/0309-1740\(82\)90095-X](https://doi.org/10.1016/0309-1740(82)90095-X)
- Liu, A., T. Nishimura, & K. Takahashi. 1996. Relationship between structural properties of intramuscular connective tissue and toughness of various chicken skeletal muscles. *Meat Sci.* 43:43-49. [https://doi.org/10.1016/0309-1740\(95\)00065-8](https://doi.org/10.1016/0309-1740(95)00065-8)
- Lizaso, G., M. J. Beriain, A. Horcada, J. Chasco, & A. Purroy. 2011. Effect of intended purpose (dairy/beef production) on beef quality. *Can. J. Anim. Sci.* 91:97-102. <https://doi.org/10.4141/CJAS10078>
- Meilgaard, M., G. V. Civille, & B. T. Carr. 2016. *Sensory Evaluation Techniques*. 5th ed. CRC Press, Florida.
- Mioč, B., V. Pavić, Z. Barać, Z. Prpić, & I. Vnućec. 2007. Milk yield of some goat breeds in Croatia. *Mljekarstvo*. 57:67-77.
- Mioč, B., Z. Prpić, I. Vnućec, Z. Barać, V. Sušić, D. Samaržija, & V. Pavić. 2008. Factors affecting goat milk yield and composition. *Mljekarstvo*. 58:305-313.
- Mishra, S., K. Kumari, & A. Dubey. 2016. Body condition of dairy cattle: A review. *RRJVS*. 2:58-65.
- National Bureau of Agricultural Commodity and Food Standards of Thailand. 2007. Halal Food (TAS 8400-2007). National Bureau of Agricultural Commodity and Food Standards, Ministry of Agriculture and Cooperatives, Bangkok, Thailand.
- National Bureau of Agricultural Commodity and Food Standards of Thailand. 2013. Good Manufacturing Practices for Goat and Sheep Abattoir (TAS 9040-2013). National Bureau of Agricultural Commodity and Food Standards, Ministry of Agriculture and Cooperatives, Bangkok, Thailand.
- Ostrowska, M., J. Jarczak, & L. Zwierzchowski. 2015. Glucose transporters in cattle – A review. *Anim. Sci. Pap. Rep.* 33:191-212.
- Palka, K. 1999. Changes in intramuscular connective tissue and collagen solubility of bovine *m. semitendinosus* during retorting. *Meat Sci.* 53:189-194. [https://doi.org/10.1016/S0309-1740\(99\)00047-9](https://doi.org/10.1016/S0309-1740(99)00047-9)
- Palka, K., & H. Daun. 1999. Changes in texture, cooking losses, and myofibrillar structure of bovine *m. semitendinosus* during heating. *Meat Sci.* 51:237-243. [https://doi.org/10.1016/S0309-1740\(98\)00119-3](https://doi.org/10.1016/S0309-1740(98)00119-3)
- Seilsuth, S., J. H. Seo, H. S. Kong, & G. J. Jeon. 2016. Microsatellite analysis of the genetic diversity and population structure in dairy goats in Thailand. *Asian Australas. J. Anim. Sci.* 29:327-332. <https://doi.org/10.5713/ajas.15.0270>
- Suman, S. P., & P. Joseph. 2013. Myoglobin chemistry and meat color. *Annu. Rev. Food Sci. Tech.* 4:79-99. <https://doi.org/10.1146/annurev-food-030212-182623>
- Suman, S. P., P. Joseph, S. Li, L. Steinke, & M. Fontaine. 2009. Primary structure of goat myoglobin. *Meat Sci.* 82:456-460. <https://doi.org/10.1016/j.meatsci.2009.02.017>
- Supakorn, C., W. Pralomkarn, & S. Tumwason. 2011. Estimation of additive, non additive gene effects and genetic parameters on pre-weaning growth traits in meat goats in southern Thailand. *Walailak J. Sci. & Tech.* 8:41-50.
- Wasiksiri, S., S. Sripongpun, A. Ratanaphan, & P. Sookras. 2013. Survey to determine the presence of the N-acetylglucosamine-6-sulfatase (G6S) gene mutation in Anglo-Nubian goats in Southern Thailand. *Thai J. Vet. Med.* 43:99-103.
- Wattanachant, S., S. Benjakul, & D. A. Ledward. 2004. Composition, color, and texture of Thai indigenous and broiler chicken muscles. *Poult. Sci.* 83:123-128. <https://doi.org/10.1093/ps/83.1.123>
- Wattanachant, S., S. Benjakul, & D. A. Ledward. 2005. Effect of heat treatment on changes in texture, structure and properties of Thai indigenous chicken muscle. *Food Chem.* 93:337-348. <https://doi.org/10.1016/j.foodchem.2004.09.032>
- Węglarz, A. 2010. Meat quality defined based on pH and colour depending on cattle category and slaughter season. *Czech J. Anim. Sci.* 55:548-556.
- Wondifraw, Z., B. M. Thombre, & D. V. Bainwad. 2013. Effect of non-genetic factors on milk production of Holstein Frisian x Deoni crossbred cows. *Int. J. Livest. Prod.* 4:106-112. <https://doi.org/10.5897/IJLP2013.0173>